Bell Atlantic and NYNEX
Overhead Loadings for DS1 and DS3 Services
Channel Termination Rates / Costs

Service Period	Bell Atlantic		NYNEX	
	DS3	DS1	DS3	DS1
Month-to-Month Service	2.06	1.70	2.01	2.57
3-Year Term Plan	1.81	1.46	1.80	2.18
5-Year Term Plan	1.27	1.30	1.30	1.92

Bell Atlantic data from Transmittal No. 883, WP 5-10

NYNEX data from ex parte in CC Docket No. 93-162 (4/18/94) and current costs and rates

OFFICE PRODUCTS

FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the matter of	)	
	)	
Price Caps Performance Review	)	**CC Docket 94-1**
for Local Exchange Carriers	)	

DECLARATION OF MELVYN A. FUSS

I, Melvyn A. Fuss, declare the following:

1. Introduction

1 My name is Melvyn A. Fuss. I am Professor of Economics at the University of Toronto, Toronto, Canada, where I have taught since 1972. I have also taught economics at Harvard University and the Hebrew University of Jerusalem. I was Chairman of the Department of Economics at Toronto during the period 1985-90, and Associate Chairman during 1984-85. I am a Research Associate of the National Bureau of Economic Research, Cambridge, Massachusetts.

2 I obtained a B.Sc. degree in mathematics and physics and a M.A. degree in economics from the University of Toronto. I received a Ph.D. degree in economics from the University of California, Berkeley.

3 My research activities have been oriented primarily toward the specification and estimation of production and cost functions and the measurement of productivity, including applications to the telecommunications sector. I have authored or edited four books and

monographs in these areas. Articles of mine in these areas of research have appeared in leading academic journals.

4 I have appeared several times as an expert witness on telecommunications productivity (and its relation to the price caps X-factor) in proceedings before The Canadian Radio, Television and Telecommunications Commission. I recently appeared before the Department of Public Utility Control of the State of Connecticut as an expert witness on Southern New England Telephone's productivity growth rate and related matters such as the input price growth rate differential. Attached to this declaration is a copy of my vitae.

5 The primary purpose of this declaration is to evaluate the tentative conclusion in Appendix F of the FCC's Performance Review Order that input price changes for local exchange carriers differ from those of the U.S. economy, and that this differential should be added to the productivity effect in the FCC's price caps formula. My main conclusion is that the inference drawn from the analysis in Appendix F is incorrect. I do not believe that the evidence in Appendix F supports the conclusion that an input price differential term should be added to the productivity term in the calculation of the X-factor.

6 I have also reviewed Christensen's simplified TFP measurement methodology currently being proposed by the United States Telephone Association. First, I strongly endorse the use of direct TFP measurement in the calculation of the productivity effect in the FCC's price caps formula. The methodology of Christensen's original study would be a more accurate way to measure the local exchange carriers' TFP than the simplified version. But that methodology requires proprietary data, and thus is odds with what I

perceive to be a requirement of the FCC that the calculations be based entirely on publically available data. The Christensen methodology seems to me to be a reasonable way of dealing with the requirement that all data used be available publically. I cannot think of any compromises that I would have handled differently. The sensitivity analysis contained in the Christensen paper demonstrates that the simplified TFP calculation remains economically meaningful and therefore useful and appropriate in establishing the productivity effect.

7 I now return to the question of the validity of the tentative assertion contained in Appendix F. In this declaration I accept, for the purpose of analysis, the assumption of the authors of Appendix F (C. Anthony Bush and Mark Uretsky), that there is a need to subject to empirical test the idea that after 1984 there was a change in the input price growth rate differential. I ask the following question: Is the FCC's tentative assertion - that the input price growth rate differential observed in the post-1984 period is a continuing phenomenon - correct? My conclusion is that the FCC's tentative assertion is incorrect because Appendix F considered only one of two possible economic explanations for the post-divestiture price differential. A more complete analysis than that carried out in Appendix F demonstrates that, assuming an input price differential developed after 1984, the correct conclusion from the data considered in Appendix F is that the differential was a temporary phenomenon that ended in 1990. This conclusion remains true when a new data point (the 1993 input price differential) is added to the data set used in Appendix F.

8 In summary, my analysis of Appendix F demonstrates that the period 1984-89 was

a temporary departure from the long term relationship between the LEC's input price growth and the U.S. economy's input price growth; and that this long term relationship was resumed in the 1990's.

2. The Basic Issue

9 The X-factor offset in the FCC's price caps formula can be written in the form

X = [TFP GROWTH (Local Exchange Carrier) - TFP GROWTH (U.S.)] (1)

10 The above formula is derived under the assumption that the expected growth rate of input prices for the LEC industry equals the expected growth rate of input prices for the US economy as a whole; i.e., the expected input price growth rate differential is zero. If the LEC industry's expected rate of growth of input prices is less than the expected rate of growth for the US economy, the X-factor offset in the price caps formula will exceed the TFP growth rate differential.

11 In its First Report and Order in the Matter of Price Cap Performance Review for Local Exchange Carriers, the FCC presented an analysis of two of its staff economists (contained in Appendix F of the First Report and Order) which argued that there was a statistically significant difference in input price growth rates in the post-divestiture period (1984-92) which should be incorporated in any price caps plan. The impact of this conclusion is quantitatively very important, resulting in an X-factor (using the data from Appendix F) which is more than double the offset calculated from equation (1). The FCC did however recognize that the conclusion of Appendix F was debatable, and called for further comment on the input price differential issue.

3. A Critical Analysis of Appendic F

(a). Introduction

12 Appendix F concluded that a statistically significant shift in the input price growth rate differential had occurred post-divestiture. The question which was left unanswered is whether that shift was temporary or permanent. In tentatively accepting the price differential add-on, the FCC assumed that the average input price differential which existed over the 1984-92 period was to be viewed as a continuing, permanent phenomenon and hence should be a component of any X-factor offset.

13 As I demonstrate below, the notion that any LEC-US input price growth rate differential is a continuing phenomenon is based on the acceptance of a specific economic hypothesis which I will call the permanent change hypothesis. The permanent change hypothesis requires that an increase in competition result in a permanent increase in the rate of technological progress.

14 A second, a priori equally plausible economic hypothesis, which I will call the temporary change hypothesis, leads to the opposite conclusion that the input price differential observed was a temporary phenomenon. The temporary change hypothesis requires that an increase in competition lead to reductions in monopoly profits earned by the LEC equipment suppliers until a more competitive profit rate is reached. The two hypotheses can be tested empirically one against the other using the data employed in Appendix F.

15 In section 3(b) I describe the two economic hypotheses in some detail. The results

of the empirical tests are presented in section 3(c).

(b). The Two Economic Hypotheses

16 The authors of Appendix F built their statistical analysis around the following argument advanced by one of the parties to the proceeding, Ad Hoc Telecommunications Users Group. Ad Hoc argued that the increase in competition in the equipment-supplying industry post-divestiture led to an increase in the productivity growth rate in this industry due to increases in technological improvements spurred on by the onset of competition. These gains in turn, it argued, led to a lower rate of increase in equipment prices than had previously been the case. I will call this the permanent change hypothesis since Ad Hoc also argued that the increase in productivity growth post-divestiture would be a permanent phenomenon.

17 Ad Hoc (and Appendix F), however, did not consider an alternative explanation for the relative decline in equipment prices in the post-divestiture period - the erosion of monopoly profits in the equipment business. Prior to 1984, a small number of equipment manufacturers such as Western Electric, the manufacturing affiliate of AT&T, and Automatic Electric, the manufacturing affiliate of GTE, had a dominant, quasi-monopoly position in the telephone equipment manufacturing industry. After divestiture, the Regional Bell Operating Companies (RBOCs) were free to purchase equipment from any supplier, but were prohibited from manufacturing equipment themselves. This aspect of the divestiture decision led to increased competition from both domestic producers and foreign producers such as Ericsson, Hitachi, Mitel, NEC, Northern Telecom, Siemens,

and others. This competition developed because the incumbent equipment manufacturers, which were not regulated, presumably had used their dominant positions in the pre-divestiture period to extract excess economic profits. Post-divestiture, these excess profits attracted the attention of rivals who were no longer foreclosed from the bulk of the market but were now able to compete on a more equal footing. The increased competition which developed post-divestiture significantly eroded the quasi-monopoly position of the incumbents and could be expected to reduce dramatically their profitability. The mechanism that would have been used by competitors to enter the industry and/or expand market share is price competition, and this has the effect of both competing away excess profits and lowering the rate of increase in the LECs' purchase prices of equipment.

18 I will call this impact on equipment prices the temporary change hypothesis, since as explained below, the competitive impact would be a temporary phenomenon.

19 The two competing hypotheses have different implications for the relative time path of equipment purchase prices and hence the time path of the input price differential. The permanent change hypothesis implies that, relative to the pre-divestiture period, after 1984 equipment prices would decline and continue to decline throughout the post-divestiture period due to increased technical progress.[1] The important implication of this hypothesis for the calculation of the X-factor is that any significant input price differential observed post-divestiture would become a permanent phenomenon.

20 The temporary change hypothesis implies that, relative to the pre-divestiture period,

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[1] This statement assumes all other things, such as general inflation and interest rates, are the same both pre- and post- divestiture.

we should observe a decline in equipment prices for several years while the competitive process eliminates the excess profits of the formally dominant firms. Once this process has run its course, equipment prices should resume a time path similar to that which existed prior to the shock caused by divestiture.

21 The implication of the temporary change hypothesis for the input price differential is that, post-divestiture, we should observe that LEC input prices are growing more slowly than input prices for the US economy for several years. After some period of time the previous equality of growth rates should be resumed. Figure 1 demonstrates the effect of the two hypotheses on the time path of the input price growth rate differential. The data point 19X represents the unknown year by which the process of competing away excess profits has been completed. This unknown year can be determined from the data, as I demonstrate in the technical appendix. Notice from figure 1 the main difference in the implications of the two competing hypotheses. In both cases LEC and US input growth rates diverge after 1984. In the case of the permanent change hypothesis, the divergence is of a continuing nature. In the case of the temporary change hypothesis, the growth rates come back together in 19X, so that considering the long term, the divergence is temporary in nature.

(c). The Empirical Results: Testing the Two Competing Hypotheses

22 The first step in the testing procedure is to determine the year 19X by which, according to the temporary change hypothesis, the process of competing away excess profits has been completed. As I demonstrate in the technical appendix, that year is 1990

for both the Christensen and NERA data sets utilized by the authors of Appendix F. The temporary change hypothesis can therefore be stated as follows: "According to the data, the process of competitive equipment price declines which competed away the excess profits of the formerly dominant incumbent equipment manufacturers occurred over the 1984-89 period. By the 1990 growth year, the growth rate of LEC input prices resumed their earlier long-term relationship with US input prices."

23 The second step of the testing procedure is to test the permanent change hypothesis against the temporary change hypothesis. In essence, the testing procedure reduces to asking the question: Which explains the data better - a continuing input price differential or one which ended after 1989?

24 The formal procedure for testing these two competing hypotheses is contained in the technical appendix. The hypotheses were tested for the Christensen and NERA data sets used in Appendix F (which involved data through 1992), and for these data sets with the addition of a 1993 data point. In <u>all</u> cases, at conventional significance levels, the permanent change hypothesis is rejected. In <u>no</u> case, at conventional significance levels, is the temporary change hypothesis rejected. The temporary change hypothesis dominates the permanent change hypothesis as a means of explaining the Christensen and NERA data sets used in Appendix F.

25 In other words, statistically one can reject the view that there is a permanent or ongoing difference between the growth rates of the LEC industry's input prices and those of the U.S. economy.

<u>(4) The Permanent Change Hypothesis - Other Evidence</u>

26 Beyond the statistical results discussed above, there is some other evidence which casts doubt on the existence of a significant ongoing input price growth rate differential.

27 The validity of the permanent change hypothesis depends on an improvement in productivity growth post-divestiture which can be attributed to an increase in technological progress. I know of only one study of the U.S. telephone equipment industry which compares productivity growth pre- and post- divestiture. This is a study by Steven Olley of New York University and Ariel Pakes of Yale University[2]. In this study, which is based on Bureau of the Census data for individual equipment manufacturing plants, the authors estimated productivity growth over the 1974-87 period. They also analyzed the sources of any productivity growth rate differential which occurred post-divestiture. Olley and Pakes estimated that productivity growth did increase post-divestiture. However, the authors found that the source of the productivity growth increase was not an increase in average productivity per plant (as would occur if technological progress accelerated), but rather was due to a reallocation of output to the more productive plants. This latter effect is not consistent with the permanent change hypothesis, because it could not be a source of continuing productivity growth. Once the reallocation was completed (perhaps after several years) this source of productivity growth increase would dry up.

28 The conclusion Olley and Pakes reach, that there is no evidence for an **increase** in technological progress that can be dated from 1984, contradicts the assumption which

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[2] "The Dynamics of Productivity in the Telecommunications Equipment Industry", National Bureau of Economic Research Working Paper No. 3977, January 1992.

underlies the analysis in Appendix F.[3]

29 The phenomenon observed by Olley and Pakes is consistent with the temporary change hypothesis. As competition eroded price levels and profits, incumbent firms would be under pressure to produce output at lowest possible cost in an attempt to maintain profit margins, and thus would reallocate production to the most efficient plants, perhaps closing the least efficient plants.

30 Another piece of evidence which contradicts the permanent change hypothesis is the testimony I presented before the Department of Public Utility Control of the State of Connecticut.[4] In that testimony I demonstrated that there was no statistically significant difference between the growth rate of input prices for the Southern New England Telephone Company and the U.S. economy for the years 1989-94.[5]

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[3] As a qualification, Olley and Pakes note in their concluding remarks that since their study ends in 1987, their results do not address the question of the effect of divestiture on the scope and productivity of R&D activity - the main source of technological progress in the industry. The implication of this qualification is that if a longer time period is considered, a significant increase in the productivity growth rate due to a permanent improvement in technical change might be observed. There does not exist more recent data as disaggregated as the Olley-Pakes plant-level data set. However, the National Bureau of Economic Research, in a publically-available manufacturing productivity data base, provide total factor productivity (TFP) estimates based on aggregate industry data for a number of SIC 4-digit industries, including SIC 3661 (Telephone and Telegraph Apparatus). The average annual TFP growth rates for selected time periods are as follows:

Time Period	TFP Growth Rate
1960-84	1.7%
1977-84	2.2%
1984-91	1.9%

There does not appear to have been a sharp increase in the TFP growth rate in the telephone and telegraph apparatus industry post-divestiture. Assuming these growth rates are applicable to the more narrowly defined telephone equipment industry, a comparison of 1984-91 with the immediately seven preceding years results in no productivity growth impact on the price differential.

[4] Docket No. 95-03-01, Request No. LFE053S, Attachment A, October 25, 1995, "Analysis of SNET's Input Price Differential 1989 to 1994".

[5] The years 1989-94 correspond to the growth years 1990 through 1994.

(5). Conclusions

31 There are two possible explanations for the change in the LEC-US input price growth rate differential which developed post-divestiture in response to competitive pressures in the telecommunications equipment industry. One, the differential could have been due to a permanent increase in the rate of technological progress in the equipment industry which would have resulted in a continuing decline in the relative rate of increase in capital prices (the permanent change hypothesis). Two, the differential could have been due to a temporary decline in the rate of increase in equipment prices resulting from the erosion of the profitability of the formerly dominant equipment suppliers (the temporary change hypothesis). Appendix F considered only the first hypothesis, and hence incorrectly concluded that the divestiture effect was permanent. I have demonstrated that a more complete statistical analysis of the data leads to a rejection of the permanent change hypothesis in favour of the temporary change hypothesis. The conclusion to be drawn from my analysis of the Christensen and NERA data sets, within the framework established in Appendix F, is that the relative decline in LEC input prices was a phenomenon of the period 1984-89 and should not play a role in the calculation of the X-factor for LEC price cap plans.

I declare, under penalty of perjury, that the foregoing is true and correct.

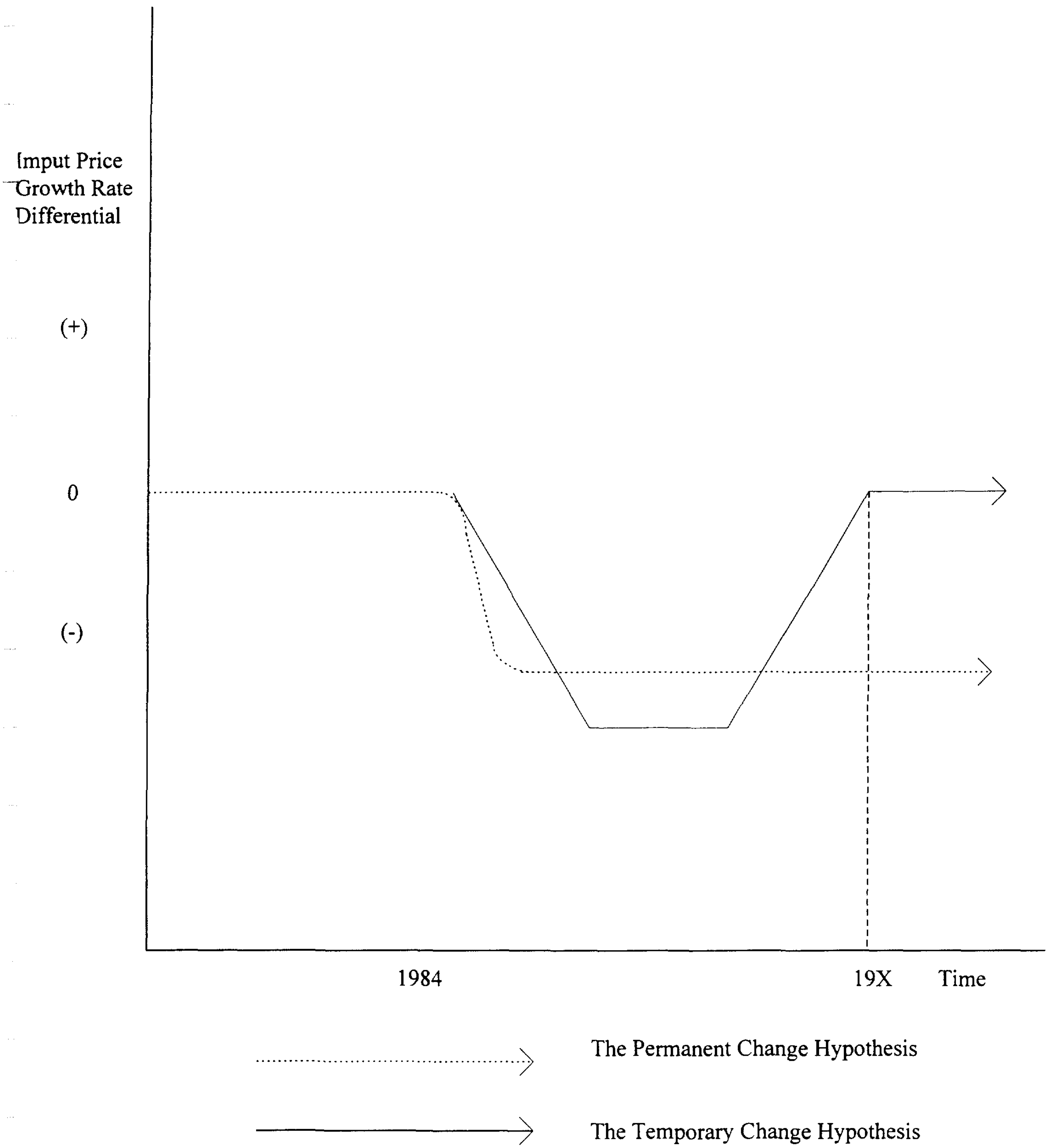
Executed on December 15, 1995

Melvyn A. Fuss

Melvyn A. Fuss

Figure 1

Competing Hypothesis Concerning the Imput Price Growth Rate Differential



Technical Appendix

(1) The Statistical Model in Appendix F and the Two Competing Hypotheses

In Appendix F, Bush and Uretsky estimate the following two models:

LEC Input Price Growth = a +b*(US Input Price Growth) +c*Divestiture + d*Moody (2)

LEC-US Input Price Growth = a + c*Divestiture +d*Moody (3)

where Moody is the yield on public utility bonds used by Christensen as the financial cost of capital, and Divestiture is a dummy variable which takes the value 1 for the years 1984-92 and 0 otherwise. The coefficients a, b, c, and d are parameters to be estimated.

If the divestiture coefficient c is negative, the data support the hypothesis of a structural shift towards lower relative LEC input price growth over the 1984-92 period, compared to an hypothesis that there was no structural change after 1984. Since the data sets used for estimation end in 1992, a value of c less than zero supports the permanent change hypothesis <u>if the additional inference is made that the 1984-92 result can be projected into the future on a continuing basis.</u>

Equations (2) and (3) can be adjusted to reflect the temporary change hypothesis by changing the definition of the dummy variable. Instead of the label "Divestiture" we will label the dummy variable DX, and construct it in the following way.

DX = 1 for the period 1984 to 19X-1

= 0 otherwise

For example, D90 will be a dummy variable which takes on the value 1 for the period 1984-89 and 0 otherwise. In other words, if D90 is the dummy variable in equations of the form (2) and

(3), the long run relationship between LEC and US input prices will exist up to 1984; a structural change will occur during the 1984-89 period; and the long-run relationship will resume after 1989 (i.e. beginning in 1990). This is just a description of the temporary change hypothesis with X=90.

The temporary change hypothesis will be represented by equations (4) and (5):

LEC Input Price Growth = a +b*(US Input Price Growth) +c*DX + d*Moody (4)

LEC-US Input Price Growth = a + c*DX +d*Moody (5)

In equations (4) and (5), X will be chosen in accordance with model selection criteria used by econometricians. The details are contained in the following section. Having chosen X, I will compare the results of equations (4) and (5) with (2) and (3). This comparison is our test of the temporary change hypothesis against the permanent change hypothesis.

(2) Model Selection for the Temporary Change Hypothesis

The criterion used to select the model to represent the temporary change hypothesis was minimization of the standard error of the regression (SER). Because the competing design matrices were all of the same dimensionality (i.e., the same number of right-hand side variables), standard error minimization results in the same decision rule as other selection criteria such as the Akaike Information Criterion (AIC), Amemiya's precision criterion (PC) and the Schwartz Criterion (SC).

Table A1 contains the values of the SER for X ranging from 85 to 92. The data sets used are the Christensen data set (1949-1992) and the NERA data set (1960-1992). The equations estimated are equations (4) and (5) from the previous section. From this table it can be seen that the SER is minimized at X=90 for all four equation - data set combinations. Hence the appropriate choice of the DX variable is D90.

Table A2 is constructed in the same way as table A1 except now a 1993 data point is added to the sample. The model selection results are invariant to the added data. The preferred choice is still DX = D90.

Since the X which satisfies the model selection criteria is X=90 for both equations (4) and (5), the temporary change hypothesis can be stated in the following way: "According to the data, the process of competitive equipment price declines which competed away the excess profits of the formerly dominant incumbent equipment manufacturers occurred over the 1984-89 period. By the 1990 growth year, the growth rate of LEC input prices resumed their earlier long-term relationship with US input prices."

(3). <u>The Comparative Regression Results</u>

Appendix F presents results of estimating equations (2) and (3) for both the NERA (1960-92) and Christensen (1949-92) data sets. In this section, I reproduce Appendix F's regression results and provide regression results for equations (4) and (5) for the same two data sets (when X=90).

<u>Christensen Data Set</u>

The regression equations estimated in Appendix F corresponding to equations (2) and (3) were (t-statistics in parenthesis):

LEC Input Price Growth = -.0027 +.3402*(US Input Price Growth)
(-0.20) (1.46)

-.0579*Divestiture +.6489*Moody (2')
(-3.81) (3.10)

R^2 = .43
Durbin Watson Statistic = 1.80

LEC-US Input Price Growth = -.0157 -.0440*Divestiture +.4080*Moody (3')
(-1.14) (-2.83) (1.78)

R^2 = .17
Durbin Watson Statistic = 2.08

The corresponding regression estimates of equations (4) and (5) with X=90 are as follows (t-statistics in parenthesis):

LEC Input Price Growth = -.0062 +.3454*(US Input Price Growth)
(-0.51) (1.71)

-.0830*DX +.6874*Moody (4')
(-5.46) (3.85)

R^2 = .56
Durbin Watson Statistic = 1.74

LEC-US Input Price Growth = -.0194 -.0703*DX +.4080*Moody (5')
(-1.55) (-4.32) (2.35)

R^2 = .32
Durbin Watson Statistic = 2.10

NERA Data Set

The regression equations estimated in Appendix F corresponding to equations (2) and (3) were (t-statistics in parenthesis):

$$\text{LEC Input Price Growth} = \underset{(-0.23)}{-.0046} \quad \underset{(\ 0.99)}{+.3140}*(\text{US Input Price Growth})$$

$$\underset{(-3.34)}{-.0480}*\text{Divestiture} \quad \underset{(\ 2.47)}{+.5794}*\text{Moody} \qquad (2'')$$

$R^2 = .44$
Durbin Watson Statistic = 2.12

$$\text{LEC-US Input Price Growth} = \underset{(-1.38)}{-.0251} \quad \underset{(-2.49)}{-.0338}*\text{Divestiture} \quad \underset{(\ 1.55)}{+.3419}*\text{Moody} \qquad (3'')$$

$R^2 = .18$
Durbin Watson Statistic = 2.01

The corresponding regression estimates of equations (4) and (5) with X=90 are as follows (t-statistics in parenthesis):

$$\text{LEC Input Price Growth} = \underset{(-0.75)}{-.0114} \quad \underset{(\ 1.20)}{+.2874}*(\text{US Input Price Growth})$$

$$\underset{(-5.97)}{-.0747}*\text{DX} \quad \underset{(\ 3.78)}{+.6857}*\text{Moody} \qquad (4'')$$

$R^2 = .66$
Durbin Watson Statistic = 2.21

$$\text{LEC-US Input Price Growth} = \underset{(-2.12)}{-.0324} \quad \underset{(-4.67)}{-.0613}*\text{DX} \quad \underset{(\ 2.46)}{+.4543}*\text{Moody} \qquad (5'')$$

$R^2 = .43$
Durbin Watson Statistic = 2.01

A comparison of equation (2) with (4), and (3) with (5) demonstrates the superiority of the temporary change hypothesis relative to the permanent change hypothesis in terms of which version fits the data better. The goodness of fit R^2 statistics are higher (.56 versus .43 and .32 versus .17 for the Christensen data set; .66 versus .44 and .43 versus .18 for the NERA data set). In addition, the important coefficients (c and d) are more significant for both data sets under the temporary change hypothesis.

While the above comparison is a heuristic, informal method of choosing between competing hypotheses, a formal procedure (described in detail in the following section) leads to the same conclusion. Using the method of non-nested hypothesis testing, (2) is rejected in favour of (4), and (3) is rejected in favour of (5). These rejections are statistically significant.

When a 1993 data point is added to the data used in Appendix F the conclusions reached in the preceding paragraph remain unchanged. (See the next section for details.)

4. Tests of the Permanent Change Hypothesis versus the Temporary Change Hypothesis

From a statistical perspective, the two hypotheses differ in the choice of the variable attached to the coefficient c in the regression equations. For this reason, the competing hypotheses are not nested in one another (i.e. one hypothesis is not a special case of the other hypothesis). The usual methods of testing hyppotheses is restricted to nested hypotheses. However, econometricians have developed procedures for testing non-nested hypotheses of the type represented in the current context. A commonly used test statistic for testing non-nested hypotheses is Davidson and MacKinnon's J Test.[1] This test can be described as follows.

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[1]Theoretical discussions of the J Test can be found in Davidson, R. and J.G. MacKinnon, "Several Tests for Model Specification in the Presence of Alternative Hypotheses", *Econometrica*, 49, 781-793, and Davidson and

Suppose the permanent change hypothesis (H1) and the temporary change hypothesis (H2) are represented by the equations

H1: $y = X_1 \beta_1$ (6)

H2: $y = X_2 \beta_2$ (7)

A composite hypothesis can be written in the form

HC: $y = (1-\alpha)(X_1 \beta_1) + \alpha(X_2 \beta_2)$ (8)

where $0 \leq \alpha \leq 1$.

The actual test involves adjusting the composite hypothesis in the following two ways:

HC1: $y = (1-\alpha)(X_1 \beta_1) + \alpha y_2$ (9)

HC2: $y = (1-\alpha)(X_2 \beta_2) + \alpha y_1$ (10)

where y_2 is a vector of the fitted values obtained by regressing y on X_2 , and y_1 is the vector of fitted values obtained by regressing y on X_1.

Davidson and McKinnon demonstrate that, when H1 is correct, the t statistic used to test whether $\alpha = 0$ in (9) is distributed in large samples as a standard normal variable. The test is equivalent to testing H1 against HC. Similarly, using a t statistic to test whether $\alpha = 0$ in (10) is equivalent to testing H2 against HC.

There are 4 possible outcomes of this testing procedure. Both H1 and H2 may be rejected ($\alpha \neq 0$ in both (9) and (10)); both H1 and H2 may not be rejected (($\alpha = 0$ in both (9) and (10)); H1 may be rejected but H2 is not ($\alpha \neq 0$ in (9) and $\alpha = 0$ in (10)); H2 may be rejected but H1 is not ($\alpha \neq 0$ in (10) and $\alpha = 0$ in (9)).

Tables A.3 and A.4 present the results of testing the various hypotheses for the

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MacKinnon, *Estimation and Inference in Econometrics*, Oxford University Press, 1993, chapter 11. A textbook presentation of the J Test can be found in Greene, W.H., *Econometric Analysis*, MacMillan, 1990, chapter 7.

Christensen and NERA data sets. Table A.3 is based on the data used in Appendix F. In all cases H1 (the permanent change hypothesis) is rejected at conventional significance levels. In no case is H2 (the temporary change hypothesis) rejected. The temporary change hypothesis clearly dominates the permanent change hypothesis as an explanation of the input price growth rate differential. The same conclusion is apparent from the results of table A.4, where a 1993 data point has been added to the data sets.

An alternative non-nested hypothesis testing procedure is the Cox Test[2], a procedure based on the likelihood ratio. To test whether H1 (the permanent change hypothesis) is correct, form the expression

$$c_{12} = (N/2)*\ln(s_2^2/s_{21}^2) \qquad (11)$$

where N is the number of observations in the sample,

s_2^2 is the regression mean residual sum of squares under H2,

$s_{21}^2 = s_1^2 + (1/N)*(b_1'X_1'M_2X_1b_1)$

where s_1^2 is the regression mean residual sum of squares under H1

b_1 is the maximum likelihood estimate of β_1

$M_2 = I-X_2(X_2'X_2)^{-1}X_2'$.

The estimated variance of c_{12} is calculated as

[2] The Cox Test was first proposed in Cox, D.R., "Tests of Separate Families of Hypotheses", *Proceedings of the Fourth Berkeley Symposium on Mathematical Statistics and Probability*, Vol. 1, University of California Press, Berkekey, 1961 and Cox, D. R. "Further Results on Tests of Separate Families of Hypotheses", *Journal of the Royal Statistical Society, Series B*, 24, 406-424. This testing procedure was derived in a regression framework by Pesaran, M.H., "On the General Problem of Model Selection", *Review of Economic Studies*, 41, 153-171. A textbook presentation of the Cox Test can be found in Greene, W.H., *Econometric Analysis*, MacMillan, 1990, chapter 7.

$$var(c_{12}) = [s_1^2/(s_{21}^2)^2][b_1'X_1'M_2M_1M_2X_1b_1] \tag{12}$$

where $M_1 = I\text{-}X_1(X_1'X_1)^{-1} X_1'$.

If the hypothesis H1 is true, the test stastistic

$$q_{12} = c_{12}/[var(c_{12})]^{1/2} \tag{13}$$

is distributed in large samples as a standard normal variable.

A test statistic to test whether H2 is correct can be obtained by interchanging the subscripts 1 and 2 in the above expressions.

As was the case with the J Test, there are four possible outcomes. H1 is correct and H2 is not; H2 is correct and H1 is not; neither H1 nor H2 is correct; both H1 and H2 are correct.

Tables A.5 and A.6 contain the results of using the Cox Test to test the competing hypotheses. In all cases H1 (the permanent change hypothsis) is rejected at conventional significance levels, whereas H2 (the temporary change hypothesis) is not. Clearly the temporary change hypothesis is the prefered explanation of the data according to the Cox Test (as well as according to the J Test).